

## Specification

### Sliding Bearing

#### Technical Field

5           The present invention relates to a sliding bearing, more particularly to a sliding bearing for an internal combustion engine, which consists of an aluminum-alloy bearing layer pressure-bonded on the backing metal, and an overlay covering the aluminum-alloy bearing layer and consisting of a solid lubricant such as  $\text{MoS}_2$  and a binder resin.

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#### Background Technique

          The present applicant has published the sliding bearing having the above-described type in Tribology Prepublished Lectures Tokyo, 1999-5 (May 10 through 12, 1999), A12. The aluminum bearing alloy used is Al-12.5Sn-2.7Si-1Cu-0.2Cr-2Pb. The  
15       solid lubricant used is  $\text{MoS}_2$ , graphite or h-BN. The binder used is epoxy resin and polyamide imide (PAI) and the like.

          A preferable composition to improve the seizure resistance and the fatigue resistance of the  $\text{MoS}_2$ -PAI based overlay is from 30 to 95 mass % of  $\text{MoS}_2$ , the balance being PAI resin.

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          In the conventional overlay, an increase in the  $\text{MoS}_2$  amount, which improves the initial conformability, is advisable to improve the seizure resistance. This method leads to reduction in the hardness of the overlay and hence to impair the wear resistance. The  $\text{MoS}_2$ -PAI-based overlay with much  $\text{MoS}_2$  is likely to wear out, so that the underlying aluminum-alloy is exposed. As a result, bearing failure such as fatigue  
25       occurs. Contrary to this, an increase in the resin amount and hence an increase in the hardness is effective for improving the wear resistance. This incurs, however, an increase in the friction coefficient and hence an increase in the initial conformability. As is described hereinabove, the  $\text{MoS}_2$ -PAI based overlay with much  $\text{MoS}_2$  can prevent the exposure of the underlying aluminum-alloy, but the seizure of the overlay and a shaft is  
30       liable to occur. It turned out that such contradictory phenomenon is prominent in a high-revolution type engine.

#### Disclosure of Invention

          The conventional overlay has been designed in such a manner that a single  
35       layer attains good performance. The present inventors recognized that : only the top part of the overlay is required to exhibit initial conformability in a high-revolution type

engine; the wear resistance of such part may be sacrificed and mild wear may be promoted; and after the conformable surface has been formed on the overlay, the conformability may be sacrificed in such a manner that the wear is suppressed and the low-friction coefficient property is realized over a long period of time. The present

5 inventors have designed a multi-layer overlay, in which the respective functions are assigned to the respective layers. More specifically, the metallic overlay, such as a Pb overlay, which is the main trend, is manufactured by electro-plating and the like. Such a manufacturing method does not involve the concept of fundamental variation in the composition of an overlay. However, under the circumstance that the metallic overlay

10 has been actually partly replaced with a resin-based overlay, a multi-layer can be easily prepared. The present inventors conceptualized that the functions of an overlay are separated in a multi-layer as described above. In addition, the fundamental function of the metallic overlay is to form a conformable surface. The fatigue resistance of the metallic overlay is inferior to that of the bearing alloy. In the academic paper mentioned

15 above, it was elucidated that the fatigue resistance of the MoS<sub>2</sub>-PAI based overlay is superior to that of the aluminum bearing-alloy. Thus, the present inventors arrived at a novel designing concept that the fatigue resistance is assigned to the overlay itself.

That is, the present invention is related to a sliding bearing, wherein an overlay, which consists of at least one solid lubricant and a binder resin, covers an

20 aluminum-alloy bearing layer bonded on the backing metal, characterized in that said overlay consists of an upper layer, which contains the solid lubricant essentially consisting of MoS<sub>2</sub>, and a layer consisting of one or both of at least one solid lubricant and at least one hard additive (hereinafter referred to as "the additive"), and, further, the MoS<sub>2</sub> gradually decreases without steps and the hard additive increases gradually

25 in the direction from the top layer to the bottom layer. The present invention is hereinafter described in detail.

In the present invention, the backing metal is a low-carbon steel sheet, an alloy-steel sheet, and the surface-treated materials of the sheets. The backing metal is metallic material, which can support the aluminum bearing-alloy usually referred to as

30 the lining, and on which the lining is pressure-bonded.

The aluminum-bearing alloy is an Al-Sn based alloy, particularly Al - 3~15 mass % Sn based alloy. Evidently, up to 4 % of the components for enhancing the wear resistance and fatigue resistance, such as Si, Cr, Cu, Mg, In, Zr, Pb and the like, may be added to the alloy component of the aluminum bearing alloy mentioned above. However,

35 since the bearing performance of the overlay is improved in the present invention, the additive components are not essential.

The upper layer of the overlay contains a solid lubricant consisting of MoS<sub>2</sub>, which exhibits excellent initial conformability. Its content is preferably from 40 to 95 mass %, more preferably from 50 to 80 mass %. A small amount of a solid lubricant other than MoS<sub>2</sub> may be used in combination.

5           The lower layer contains one or both of the solid lubricants or the hard additives (additives). The amount of the additives is preferably from 30 to 85 mass %, more preferably from 30 to 60 mass %. When the solid lubricant consists only of MoS<sub>2</sub> or is a combination of MoS<sub>2</sub> and other component(s), the content of MoS<sub>2</sub> in the lower layer should be relatively lower than that in the upper layer. The MoS<sub>2</sub> content of the upper  
10 layer is higher than that of the lower layer by preferably 10% or more, more preferably by 15 to 20%.

The solid lubricant of the lower layer may be graphite, zinc sulfide, tungsten disulfide and/or hexagonal boron nitride which replaces MoS<sub>2</sub> or is added in addition to MoS<sub>2</sub>.

15           The hard additive is specifically at least one selected from the group consisting of Si<sub>3</sub>N<sub>4</sub>, SiO<sub>2</sub>, SiC and Al<sub>2</sub>O<sub>3</sub>. The content is preferably from 0.1 to 10 mass %, more preferably from 1 to 5 mass %.

In the present invention, the components and composition of the upper and lower layers are constant in the respective layer. If necessary, the upper layer may be  
20 embodied as two or more sub-layers having different MoS<sub>2</sub> content. The MoS<sub>2</sub> content of the upper sub-layer is greater than that of the lower sub-layer, thereby forming a concentration gradient. In this embodiment, the initial conformability of the upper layer is attained at a furthermore higher level. Likewise, the lower layer may be embodied as two or more sub-layers having different content of the additive. The additive content of  
25 the upper sub-layer is greater than that of the lower sub-layer, thereby forming a concentration gradient. In this embodiment, the wear resistance of the lower layer can be realized for an extended sliding distance. The upper layer having the concentration gradient as described above has a higher average MoS<sub>2</sub> content than the average MoS<sub>2</sub> content of the lower layer. More preferably, the gradient of MoS<sub>2</sub> concentration is  
30 established in the entire overlay. The particle diameter of the additive is not particularly limited, but the average diameter is preferably in the range of from 0.1 to 2 μm.

The binder resin preferably used is polyamide imide.

35           The overlay according to the present invention may be an inclined layer structure consisting of an upper layer, an intermediate layer and a lower layer. The intermediate layer has the identical component as that of either of the upper layer

having a single composition or the lower layer having a single composition. In addition, the composition of the upper and lower layers may not be distinctly differentiated. That is, not stepwise but gradual decrease of MoS<sub>2</sub> and increase of hard additive from the upper and lower layers may be carried out. No adherence problem between the upper and lower layer occurs, so that stable initial conformability and wear resistance can be attained.

The overlay is preferably from 2 to 15  $\mu$  m thick, more preferably from 3 to 9  $\mu$  m thick. The upper layer is preferably from 1 to 5  $\mu$  m thick, more preferably from 2 to 4  $\mu$  m thick.

The upper and lower layers according to the present invention can be prepared by means of applying on the cleaned surface of aluminum-alloy the resin, which contains a predetermined additive, and subsequently curing at 180 to 270°C. That is, neither special surface treatment nor polishing is carried out after the curing.

The present invention is hereinafter described with reference to Examples and Comparative Examples.

#### Best Mode for Carrying Out the Invention.

The upper layer (2  $\mu$  m of thickness), the intermediate layer (1  $\mu$  m of thickness), and the lower layer (4  $\mu$  m of thickness) having the compositions shown in Table 1 were formed on the aluminum-bearing alloy (composition – Al-Sn based). The aluminum alloy was pressure-bonded on a low-carbon steel sheet by a conventional method. The balance of the additive is polyamide imide. The sliding bearings produced as described above were subjected to the seizure-resistant test and wear-resistant test described below.

#### Seizure Resistant Test

Tester: high surface-pressure bearing tester

Opposed shaft: S55C (quenching hardened)

Lubrication: oil-supply to a shaft

Method for imparting load: successive increase

#### Wear Resistant Test

Tester: rotary load tester

Opposed shaft: S55C (quenching hardened)

Lubrication: oil-supply into a shaft

Load: static load

The results of the test are shown in Table 1.

Table 1

Upper Layer MoS <sub>2</sub>	Intermediate Layer		Lower Layer		Results		Remarks
	MoS <sub>2</sub>	Hard Matter	MoS <sub>2</sub>	Hard Additive	Seizure Surface Pressure	Wear Amount	
55%	55%	1%Si <sub>3</sub> N <sub>4</sub>	40%	1% Si <sub>3</sub> N <sub>4</sub>	75MPa	1 μm	Example 1
↑	↑	3% Si <sub>3</sub> N <sub>4</sub>	↑	3% Si <sub>3</sub> N <sub>4</sub>	75MPa	1 μm	Example 2
70%	70%	1% Si <sub>3</sub> N <sub>4</sub>	40%	1% Si <sub>3</sub> N <sub>4</sub>	80MPa	3 μm	Example 3
↑	↑	↑	30%	↑	80MPa	2 μm	Example 4
↑	↑	1%BN	↑	1%BN	80MPa	2 μm	Example 5
↑	↑	1%ZnS	↑	1%ZnS	80MPa	2 μm	Example 6
40%MoS <sub>2</sub>					60MPa	1 μm	Comparative Material(Single Layer)
70%MoS <sub>2</sub>					55MPa	5 μm	Comparative Material(Single Layer)

### Industrial Applicability

As is described hereinabove, the overlay consists of an upper layer and a lower layer. Importance is attached to the upper layer with regard to the conformability. Importance is attached to the lower layer with regard to the wear resistance. As a result, the seizure resistance can be increased, while the wear resistance can be kept to a low level.